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The potential for e-biking among the younger population: a study of Dutch students

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Abstract

This study assessed the benefits and limitations of e-bike use for students participating in a pilot in a university town in the Netherlands. It targets a gap in the literature regarding e-bike use in early adulthood. Thirty-seven pilot participants completed a survey on their e-bike experiences, and follow-up in-depth interviews were held with eight participants. Results suggest there is a considerable potential for e-bike use among students. Participants valued e-bike speed, ease of use, the enjoyable experience of assisted cycling and independency from public transport schedules. Main impediments were the high costs of e-bikes, which have to compete with low-cost regular bikes and free public transportation. The study was based on a small, non-representative sample. Self-selection of participants and self-report of travel behaviors may have affected the internal and external validity of the results. Yet, the study offers first insights in the potential for e-bike use among younger populations. The positive attitudes of students suggest increased acceptance of e-bikes for everyday use, and likelihood of use in later life. Insights may guide future development of sustainable transport systems in university environments specifically and society in general. Results reveal a high potential for e-bikes to substitute public transportation use, but the high purchasing price makes it difficult for the e-bike to compete with other transport modes.

Key words – Electrically-assisted cycling, university towns, sustainable transport, mobility behavior, commuting

1. Introduction

Electrically-assisted cycling, or e-biking, is growing in popularity in many countries across the world (Fishman & Cherry 2015). E-bikes combine propulsion by user pedaling with assistance through a computer-guided electric motor. They permit cycling at constant and augmented speeds against reduced physical effort, and enable cyclists to cover longer distances in shorter amounts of time. Together with high energy efficiency compared to conventional motorized transportation, this makes them potentially effective in reducing traffic congestion, associated environmental problems, and increasing users' physical activity levels. Thus, e-bikes can be considered a viable alternative to conventional motorized transport on distances too long to cover by regular bike (Fyhri & Fearnley 2015).

Case studies in Europe, North America and Australia have suggested that e-bike use is especially high among middle-aged and older adults (Fishman & Cherry 2015). Little is known about its potential among younger populations. Yet, stimulation of e-bike adoption in early adulthood may help to reduce demands on public transportation systems and can possibly substitute younger adults' use of conventional motorized transportation now and in later life.

The present study aimed to gain insight in the potential benefits and limitations of e-bike use for young adults by evaluating an e-bike pilot among university students. These insights may be used to develop indicators of future e-bike use in this population and prospective developments in e-bike mobility in general. Before presenting the method and results of the study, we first discuss university students' travel behavior, determinants of behavior change, and we briefly review the current knowledge on e-bike mobility.

a. Student travel behavior

There is a general lack of understanding regarding university student travel behavior. Many travel behavior studies are not inclusive of the unique travel patterns of students that are closely tied to university land use, class schedules, recreation and work (Eom et al. 2009). Yet, as pointed out by Balsas (2003), the distinctive character of university student environments offers unique opportunities for communicating sustainability practices and shaping future transportation patterns. As such, positive experiences with sustainable modes of transport during university years can potentially play an important role in encouraging sustainable travel behaviors (Zhou 2012).

The majority of student travel behavior studies to date have focused on U.S. university campus environments. Eom et al. (2009) found that walking was a prime mode for students

living on-campus at the North Carolina State University, while driving was the prime mode for off-campus residents. Walking or driving to the university may also be dependent on commuting distance. For example, a study by Chen (2012) stressed differences between college-town and urban universities, with the latter having higher rates of motorized (public) transport use among students due to longer commuting distances. Other possible factors of influence on student travel behavior are climate and weather. A study at the University of California Los Angeles demonstrated generally high rates of cycling, walking and public transport use, which potentially relate to the favorable climate (Zhou 2012). Indeed, a study at the University of Idaho showed important fluctuations in mode use due to seasonal variations (Delmelle & Delmelle 2012). Another study at Kent State University in Ohio showed low walking and cycling shares throughout the year (Kaplan 2015), although it was pointed out that weather was but one factor alongside time pressure, busy streets, safety concerns and supportive infrastructures for walking and cycling. In sum, important factors in modal travel choice of U.S. students seem to be distance, weather conditions and the presence of walking and cycling-friendly environments.

Despite the barriers, U.S. cycling rates appear to be generally higher among students than in the general population (Pucher et al. 1999). The same seems to apply to the western European context. High rates of cycling in cities such as Groningen, Enschede (the Netherlands), Münster, Freiburg (Germany), Ghent (Belgium) and Odense (Denmark) correlate with the presence of large student populations (see Fietsberaad 2006). A possible explanation is the low barrier of entry in terms of cost, and the potential to save money when cycling to the university instead of using other modes (Shannon et al. 2006, p.247). In some countries, student populations are also eligible to free or discounted public transport use (De Witte et al. 2006). This is, for example, the case in the Netherlands, where high use of congested urban public transport by students has provided an impetus for attempts at modal shifts from train and bus to cycling and other forms of active commuting. In this context, the general need to decrease reliance on conventional motorized transport makes e-bikes a potentially interesting form of active travel to complement shares of walking and regular cycling in the Netherlands.

b. Determinants of travel behavior

Research on people's willingness to switch to environmentally friendly modes of transport has revealed that travel behavior, like most daily behaviors, ensues from automatic processes or habits (Müggenburg et al. 2015). Such habits permit to avoid continuously thinking about

what we do, and therefore more efficiently allocate cognitive capacity to other tasks (Klöckner & Verplanken 2013). In particular the daily routine of commuting has been found to be strongly determined by habitual processes. This firmly embedded routine typically overrides conscious decision-making behavior (Guell et al. 2012). However, infrequent or major life events can tilt routines and offer opportunities for shifting commuting habits. These key events can interrupt habits and start a re-evaluation of mobility behavior through active decision-making strategies (Müggenburg et al. 2015). Previous studies have stressed the importance of experiencing e-bikes firsthand. The opportunity to try an e-bike for an extended period of time can potentially start the process of re-evaluating habits (Popovich et al. 2014; Fietsberaad 2013).

To students, the disruptive effect of trying an e-bike on commuting habits will depend on the extent to which it suits their particular lifestyle. Also, it will have to offer distinct qualities compared to other transport modes. Aspects for consideration are mode safety, reliability, speed, ease of use, comfort and an enjoyable experience (Van Hagen 2011). We briefly discuss previous research on the qualities and impacts of e-bikes in the next section.

c. Research on e-bike mobility

Much of the existing research on e-bike mobility has been conducted in China (Ji et al. 2012). The high rates of Chinese adoption of scooter-style e-bikes, followed by a surge in e-bike rider injuries and fatalities, led to an abundance of studies on e-bike safety (Bai et al. 2015). Transferability of these insights to other contexts is limited, as in Europe and North America bicycle-style e-bikes are more common (Dill & Rose 2012). Nonetheless, safety remains an important issue. This is due in part to the popularity among older adults (Fietsberaad 2013). First evidence shows that in particular older and physically impaired e-bike crash victims are more likely to be hospitalized than victims of accidents with regular bikes (Schepers et al. 2014). Generally speaking, e-bikes seem to present slightly greater risks than regular bikes, which may be largely due to their higher speed (Schepers et al. 2014; Vlakveld et al. 2015).

Yet, speed seems to be the most distinctive characteristic of e-bikes and a major contributor to positive user experiences (Popovich et al. 2014). It has also been suggested that e-bikes' elevated speeds facilitate competition with local public transport and rush-hour driving (Fyhri & Fearnley 2015). Related to speed is the reduced physical effort due to pedal assistance, which permits bridging longer distances and more complicated journeys. Jones et al (2016) found that this is an important motivation for using e-bikes. Also, pedal assistance could allow parents to more easily transport small children. However, e-bike batteries, which

give e-bikes their initial advantage, also restrict ease of use by adding to the weight and thus limiting cycling range and levels of assistance (Rose 2012). Furthermore, battery visibility might in some cases add to the social stigma of assisted cycling being 'cheating' (Jones et al. 2016).

Finally, an important issue in e-bike mobility research is health. Assisted cycling requires lower levels of physical activity compared to conventional cycling. This is, among other things, reflected in lower cardiovascular and metabolic effort and less respiratory exchange (Sperlich et al. 2012). Other studies have demonstrated lower cycling intensities for assisted versus non-assisted cycling (Simons et al. 2009; Gojanovic et al. 2011). Nonetheless, while beneficial effects are clearly highest when substituting motorized travel, these studies conclude that assisted cycling offers sufficient physical activity to comply with moderate-intensity standards and thus promote good general health (Sperlich et al. 2012; Simons et al. 2009; Gojanovic et al. 2011).

In the remainder of this article, we present the details of a study on e-bike use among university students in the town of Groningen, the Netherlands. The study was conducted as part of a pilot initiated to explore the potential of the e-bike for reducing extensive use of public transport by students. We used this unique opportunity to examine students' personal experiences with e-bikes, which have thus far received little attention in the literature.

2. Method

a. The pilot

In the spring of 2015 the local mobility office *Groningen Bereikbaar* organized e-bike pilots at several educational institutions in the city of Groningen (200.000 inhabitants). One pilot was conducted among students of the University of Groningen (30,000 students). The city of Groningen, located in the Northern part of the Netherlands, is known for its high share of bike use. This is the result of long-standing policy efforts in compact city planning, traffic management and the development of an extensive and coherent bike infrastructure network (Fietsberaad 2006). Yet, traffic in the city often gets congested because many students make intensive use of buses and trains, which they can ride for free using a student transit pass. The university pilot was set out to investigate whether the e-bike might substitute the high use of buses and trains, and thereby may help to reduce students' reliance on public transportation. Pilot participants were recruited through the university, and e-bikes were supplied by a commercial third party. Regular model e-bikes were used in the pilot, legally defined as requiring propulsion by user pedaling and offering assistance up to 25 km/h. For this type of

e-bike, driver's license, insurance or helmet use are not mandatory, and the same traffic laws apply as for conventional cyclists (Fietsberaad 2013). A total of 41 university students participated in the pilot from February to May 2015, each using the e-bike for four to five weeks. At the end, they were offered the possibility of buying an e-bike at a reduced price. When returning the e-bike, students were asked to fill out a survey. Students who completed the survey were then approached by the researchers for a follow-up in-depth interview.

b. Survey

Of the 41 students who participated in the pilot, 37 completed the survey (22 men, 15 women). It was designed by the initiators of the pilot, and researchers were not involved in the process. The survey comprised 16 questions, divided into five parts. In the first part participants were asked about their travel behavior before and during the pilot using trip counts by mode per week. The second part consisted of questions about participants' motivations and experiences Participants could indicate their main reason for participating in the pilot from a checklist with response options 'try an e-bike', 'see whether it is a suitable alternative to public transportation', 'see if it is faster', and 'other'. They were also asked whether their expectations were met (answer options 'yes' or 'no', with the option of explaining the reason for their response). In the third part participants were asked to rate their experiences with the e-bike, with the options 'very good', 'good', 'fair', 'poor' and 'very poor', and the option of explaining the reason for their response. An additional set of nine statements addressed issues such as experience, ease of use, physical activity, safety and image (e.g.: "Using an e-bike is fun"), with answer options 'strongly agree', 'agree', 'agree nor disagree', 'disagree', 'strongly disagree'. In the fourth part of the survey participants were asked whether they had bought an e-bike or were planning on doing so, and which factors would help facilitate that decision (response options: 'price discount', 'rent with option to buy', 'lease', 'provision of charging facilities'). Finally, the fifth part of the survey asked participants whether sustainability had played a role in their decision to participate in the pilot (response options 'yes' or 'no', with motivation) and whether they considered the e-bike to be sustainable (open-ended).

c. Interviews

Semi-structured in-depth interviews with eight students (4 men, 4 women, mean age=25, *SD*=9.4) were conducted to complement the survey data. We first recreated interview participants' activity spaces by mapping the origins and destinations of the commute and

additional destinations reached by e-bike. This map served as a primer for the remainder of the interview with the purpose of aiding participants' remembrance of travel behavior and destinations reached during the pilot. Prior to the interviews we developed an interview guide based on elements of travel mode satisfaction such as safety, reliability, speed, ease of use, comfort and experience (Van Hagen 2011). A grounded theory approach was used for interview coding (Hennink et al. 2011). Verbatim transcripts were anonymized and coded using Atlas.ti. The resulting codebook was expanded and refined throughout the coding process. Citations that supported conclusions were translated from Dutch to English by the authors. To preserve confidentiality, all participants are referred to by their participant numbers.

3. Results

a. Survey

Travel behavior

Table 1 provides an overview of participants' self-reported travel behavior in an average week before and during the pilot. During the pilot phase, e-bike use increased significantly from 0% to 87.0% of the total number of trips in an average week. This increase occurred mostly at the cost of regular bike-use, which went down significantly from 56.3% to 5.1%. Bus use was also significantly reduced from 20.8% to 2.3% during the pilot, as was combined bus/bike use from 2.0 to 0.0%. The use of other transport modes (car use and walking) was also significantly reduced from 14.3% to 3.3%. Although the use of the train, and combined train/bus trips were somewhat reduced, these decreases were not significant. In general, the introduction of the e-bike during the pilot period led to a shift from the regular bike and bus as dominant transport modes to the e-bike as the dominant transport mode.

Table 1 – Numbers and percentages of commuting trips by mode in an average week before and during the e-bike pilot

	Before pilot		**During pilot**		**Difference**	
	Nr of trips	%	Nr of trips	%	Chi^2	*p*-value
E-bike	0	0	187	87.0	359.06	<.001
Bike	138	56.3	11	5.1	137.13	<.001
Bus	51	20.8	5	2.3	36.62	<.001
Train	8	3.3	2	0.9	2.94	.087
Bike+bus	5	2.0	0	0	4.44	.035
Bus+train	8	3.3	3	1.4	1.72	.190
Other	35	14.3	7	3.3	16.79	<.001
Total	245	100.0	215	100.0		

Respondents sometimes indicated that multiple modes were used before and during the pilot. Therefore, it was not possible to correctly assess mode substitution for all trips made. However, of e-bike trips that fully substituted trips done before the pilot (n=155), 58.3% were previously done by bike, 25.2% by bus, 3.3% by train, 3.3% by bus/train, 1.3% by bike/bus, and 8.6% was previously done using other modes (car or walking).

Motivations and expectations

The main reason for participants to participate in the pilot was to 'try out an e-bike' (checked by 66% of the participants). The option see if it is faster' was checked by 22% of the participants, while the least checked reason was 'see whether it is a suitable alternative to public transportation' (11%). The majority (89%) stated that the e-bike lived up to their expectations.

Experiences

Students were almost unanimously positive about the e-bike, rating the experience as 'great' (46%), 'good' (49%), or 'fair' (5%). Analysis of the comments reveals that the most commonly mentioned positive experiences were related to speed (mentioned 21 times, using words such as "fast" and "faster"), physical exercise (mentioned 12 times, using terms like "not/less tired", "not/less sweaty") and ease of use and comfort (mentioned 11 times). Three participants also mentioned negative aspects, stating that "the e-bike could go a little faster", "it is a bit old-fashioned", and "the battery runs low really quick. The majority of the participants also agreed that the e-bike was convenient to commute to and from the university (84%). Again, convenience was mostly linked to speed (mentioned 15 times), but ease of use,

saving time, independency from transit schedules and being less sweaty/tired upon arrival were also mentioned.

Figure 1 provides an overview of the responses to the nine statements on e-bike use. All participants agreed that using an e-bike is fun and that the e-bike is easy to use. Nearly all participants (97%) also agreed that they would like to own an e-bike, that the e-bike is an appealing alternative to the conventional bike (94%), and that the e-bike enables them to arrive at their destination without sweating (94%). A large majority also agreed with statements about the e-bike as an appealing alternative to public transportation (78%), easy charging of the battery (86%), and feeling safe in traffic when cycling on the e-bike (81%), while a large majority (67%) disagreed that the e-bike is mostly interesting for older adults. However, responses to these latter four statements were somewhat more ambivalent than responses to the other statements.

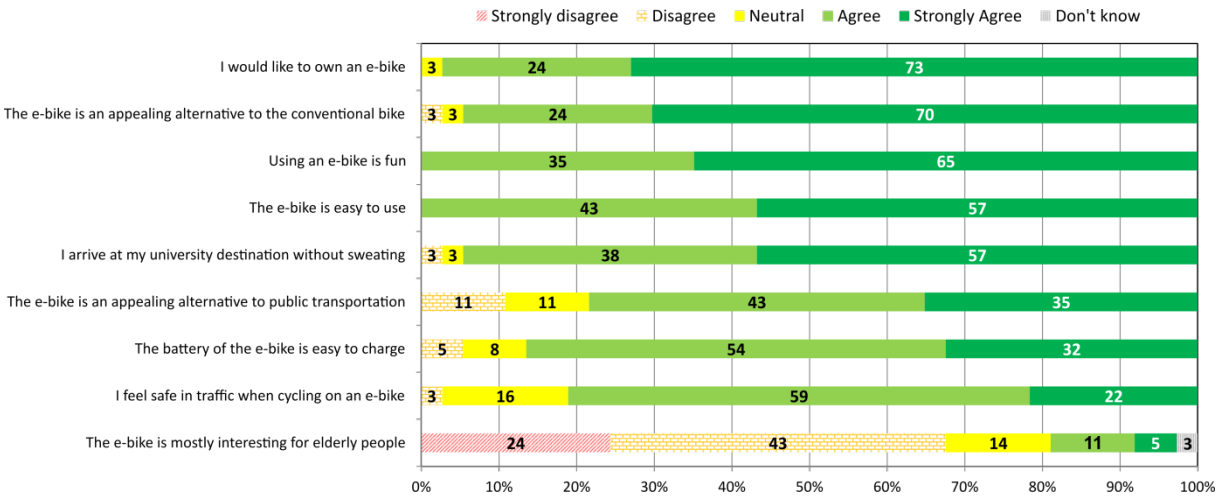

Figure 1 - Responses to nine survey statements on aspects of e-bike use (data labels in %)

Table 2 provides an overview of the correlations between participants' responses to the nine statements about e-bike use. The strongest positive correlations were found between the desire to own an e-bike and the statements that riding an e-bike is fun and that it is an appealing alternative to public transportation. There was also a strong, positive correlation between the view that it was an appealing alternative to conventional bike use and the statements that e-bike use was fun, that it was an appealing alternative to public transport, and the expressed desire to own an e-bike. A strong positive correlation was equally found between the view that the e-bike was fun to use, and statements that it was an appealing alternative to public transport and that it permitted to arrive at the university without sweating. Arriving without sweating was also found to strongly correlate with the statement that it was easy to charge.

Finally, a strong negative correlation was found between the view that the e-bike was an appealing alternative to public transport use, and the view that e-bikes were mostly suited for older people.

Table 2 – Correlations between statements about various aspects of e-bike use

	1	2	3	4	5	6	7	8	9
1. Would like own an e-bike	1.00								
2. Alternative to conventional bike	.46**	1.00							
3. E-bike is fun	,57***	.51**	1.00						
4. E-bike is easy to use	.13	.40*	.39*	1.00					
5. Arrive without sweating	.18	.17	.44**	.38*	1.00				
6. Alternative to public transport	.63***	.44**	.44**	.14	.40*	1.00			
7. E-bike is easy to charge	.24	.10	.20	.36*	.49**	.25	1.00		
8. I feel safe in traffic	.23	.23	.33	.31	.28	.04	.25	1.00	
9. Mostly for older people	-.24	-.25	-.09	-.04	-.03	-.33*	-.08	.12	1.00

* = $p < .05$, ** = $p < .01$, *** $p < .001$; *Due to missing data, analyses are based on responses of 37 out of 41 participants*

Future intentions

When asked how they thought about buying an e-bike, a large majority of the respondents (81%) stated that they had had a positive experience, but were not planning on buying an e-bike yet. Six participants considered buying an e-bike, whereas only one participant was "for sure going to buy an e-bike". This participant currently commuted by bus, and indicated that independency from public transit schedules would be an important motivator. In general, when asked under which circumstances they would consider buying an e-bike, survey respondents mostly indicated "when the e-bike gets cheaper" (84%) and "if an appealing financing scheme is offered" (43%).

Sustainability issues

Finally, the majority of participants (59%) stated that environmental issues were no motivation for participation in the e-bike pilot. Sixty-two percent of the participants stated that they had used less motorized transport during the pilot. To some of the participants (16%), using the e-bike did not feel sustainable, as they previously used a conventional bike. Three participants (8%) saw the e-bike as more environmental-friendly than the bus, but also noted that the energy use of the e-bike made it less sustainable than regular cycling.

b. Interviews

Figure 2 shows the origins and destinations of the eight interviewees. Interviewee characteristics are detailed in table 3. Two lived in an inner suburb, four in an outer suburb,

and two outside the city. Most participants were young adults in the age between 18 and 27 year. One participant was an older student aged 48. We included this older participant because she lived at a longer distance from the university and previously travelled mainly by car. This enabled us to gain some insight into the benefits and limitations of the e-bike compared to the car.

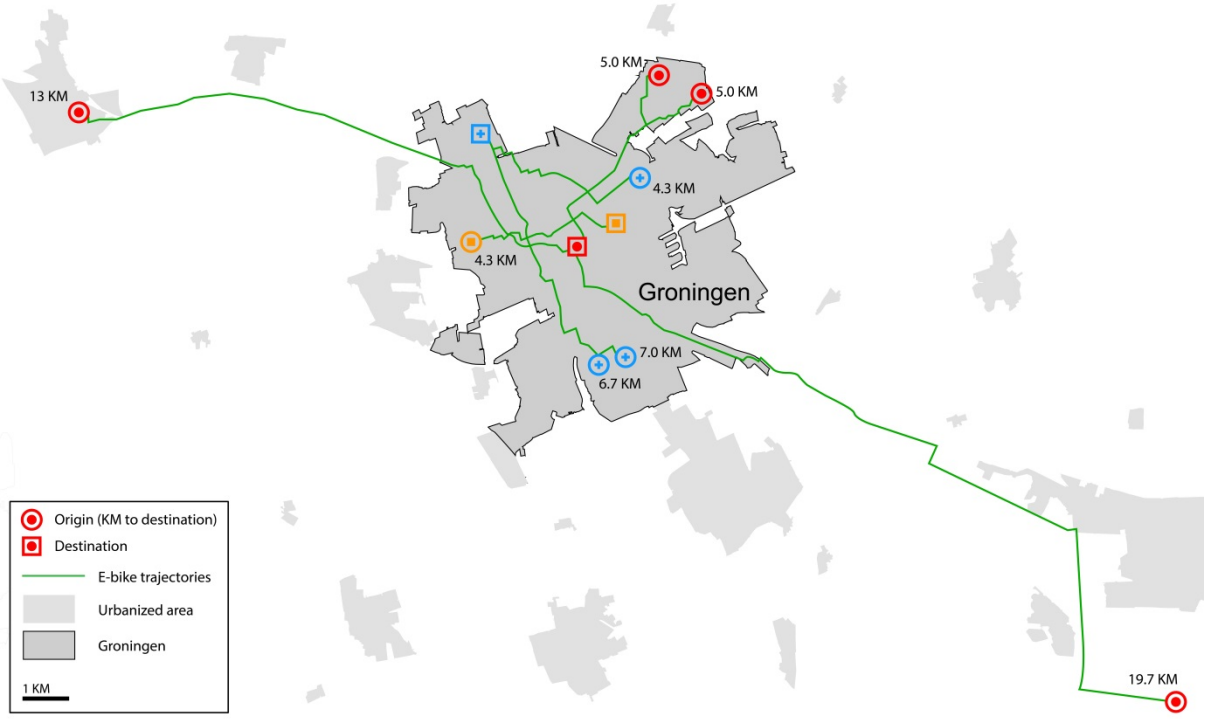

Figure 2 - Interviewees' origins, destinations, e-bike commuting routes and distances

Table 3 – Interviewee characteristics

Interviewee	Age	Sex	Distance to university	Main commuting mode before pilot	Alternative commuting mode before pilot
1	23	F	4.3	Bike	Bus
2	21	M	7.0	Bike	Bus
3	23	M	6.7	Bus	Bus
4	24	M	4.3	Bike	Bus
5	27	M	5.0	Bike	Car
6	21	F	5.0	Bus	Bike
7	18	F	13.0	Train	Bike
8	48	F	19.7	Car	None

The most mentioned reasons for using the main commuting mode were that the mode was the fastest, had the most direct route, or offered time control. Choice for alternative

modes was mostly related to the weather. Most interviewees had clear expectations of e-bike use before the pilot, anticipating less physical effort (mentioned three times), faster commutes (mentioned two times), and easy use (mentioned two times). Yet, two interviewees explicitly stated not knowing what to expect. Others indicated that they had been hesitant to participate at first as they considered the e-bike something for older adults or "lazy individuals".

> "*I thought, an e-bike, that's something for softies, I really don't need that*" (Interviewee 2)

In line with the survey results, interviewees were unanimously positive about the e-bike in retrospect. They praised speed (mentioned four times), and ease of use and reduced effort (both mentioned three times). Most interviewees also achieved a reduction of their travel times.

> "*I noticed I didn't have to leave 30 or 35 minutes in advance anymore. If I left 20 minutes in advance, that would do. I'd have more time*" (Interviewee 4)

Concerning physical effort, headwind proved less influential, which resulted in being less sweaty on arrival compared to using a regular bike.

> *"I have to cross all these fields. That's where you notice the difference, since there's usually so much wind there*" (Interviewee 7)

Interviewees mentioned differences in preparing for the commute. One interviewee better prepared her clothing and gear, and charged music onto her phone for the longer commute. Others mentioned e-bike charging as an extra action to get used to.

> *"Ten minutes before leaving, I'd have to start putting on my gear, my raincoat, my headphones (..) but I got used to that, it wasn't a big deal"* (Interviewee 8)

> *"Every day, I would take the battery out, so first thing in, I would put the battery back in, and then get on my bike*" (Interviewee 4)

> "*It's not a lot of extra actions, but you have more things to think about*" (Interviewee 3)

i. Safety & reliability

Interviewees felt safe, but needed some time to get accustomed to the e-bike. Seven interviewees indicated that the elevated speed contributed to hazardous situations. Shifting gears and judging other road users sometimes proved problematic.

> "*It took me a couple of days to find out how fast I could go on different intersections, when to shift gears*" (Interviewee 8)

> "*In the beginning, I didn't even think of the possibility that it could be more dangerous. Then, I almost fell of my bike, and I realized I had to adapt, I had to mind my speed in the bends*" (Interviewee 5)

In response to the question how they dealt with relative unsafety, participants mentioned taking the time to get used to the bike and more pro-active cycling. Higher speeds also led to differences in dealing with fellow road users. Interviewees mostly felt these issues were a matter of cyclists' own responsibility, and that further regulation was not required. Yet, some reckoned that regulations could be desirable to ensure safety for some groups of people, for instance older adults or the very young.

> *"I see regulation as a last resort, for when the day comes that people can't think for themselves anymore. (..) How do you enforce e-bike laws and regulations? It's such a rigorous measure"* (Interviewee 4)

> *"If you're considerate, if you are careful, it shouldn't be that dangerous. Same goes for people cycling high speeds on a conventional bike*" (Interviewee 5)

Activity space mapping showed that all interviewees also used the e-bike for other purposes than commuting, such as grocery shopping (mentioned by 6 interviewees), going to the library (mentioned by 4 interviewees), attending social events (mentioned by 3 interviewees), and recreational riding (mentioned by 2 interviewees).

Figure 3 shows a map of the different activities that interviewee 4 undertook with his e-bike.

Figure 3 - Destinations reached by e-bike by one interviewee during the pilot

Several participants stated that the e-bike enabled them to more easily combine activities.

> *"Coming home late, you would more easily be inclined to go to campus and go work out than with the regular bike, because you can get there really fast. Using the conventional bike, I would pass. Using the e-bike, well, I get there quickly*" (Interviewee 3)

Finally, we probed the technical complexity of the e-bike. Most interviewees were confident to solve minor issues that resemble those of a regular bike such as gears, brakes or tires. However, problems concerning electronics and propulsion mechanics would require help from the outside. To cover the costs of such repairs, most interviewees indicated a willingness to consider leasing a bike in the future if a maintenance service is included.

ii. Speed & ease of use

In line with the survey results, interviewees greatly enjoyed the speed of the e-bike. Yet, they would have liked pedal assistance at higher speeds.

> "*The first time at full speed, I thought 'wow, it's so fast!' But you get used to that, and on the longer sections I would think, 'faster, faster'!*" (Interviewee 6)

> "*I think it's no different from my regular cycling speed. I think it could go faster. But then again, I would probably also say that if the assistance was 35 km/h. It's never enough*" (Interviewee 3)

As a consequence of increased speeds, interviewees were busier overtaking other cyclists and generally more alert when cycling. Especially during rush hours, participants were not always able to cycle at full speeds. For most participants, however, having an e-bike did not lead to taking different routes. One interviewee mentioned having changed routes from the usual commute, arguing that minimized effort offered possibilities to try other routes that might be more fun. Furthermore, interviewees mentioned the convenience of higher speed in relation to bridges (mentioned 3 times), and headwind and long, straight sections of bike paths (both mentioned 4 times). Finally, the easier acceleration offered by the electrical assistance meant that interviewees felt less hindered by stops along the way, such as traffic lights or intersections.

We probed ease of use of the e-bike and consequences for mental effort. Half of the participants mentioned little to no significant changes to their commuting routines which affected that ease. Two interviewees mentioned calmer commutes. The most important consequences of e-bike use were slight changes in time and day planning, which were generally experienced as positive. For six out of eight interviewees, the e-bike meant a shorter travel time and thus time gain, translating in an earlier arrival for some, but meaning leaving home later for others.

> "*Leaving home at the same time, I would get here earlier, meaning less of a hurry to get to class. I could get a coffee, or fill my water bottle, so it's a calmer commute*". (Interviewee 4)

Independence from bus and train schedules was repeatedly mentioned as an important advantage. However, bike parking then became an issue. Six out of eight interviewees agreed

that the e-bike was more prone to theft than their regular bike, the other two were neutral. Although some stated to better lock the bike or park it inside their home, others said not having done anything different.

> "*Around where I live, bike theft is very common. And to be honest, I was surprised that this one didn't get stolen*" (Interviewee 4)

> "*I double-locked the bike, as to not invite people to steal it. But then again, that's what I always do*" (Interviewee 1)

iii. Physical effort, comfort and experience

Overall, interviewees agreed that using the e-bike led to changes in physical exercise. It led to reduced or no fatigue, less sweating and less strain compared with regular cycling. Apart from mentioning the pleasures of more comfortable commuting, three interviewees said the e-bike brought them a well-needed increase in physical activity.

> *"Traveling by train is really passive. Riding the e-bike, you're actually putting in effort (..) and it gives you the feeling of doing good!"* (Interviewee 7)

Yet, for two interviewees this would be a reason not to buy an e-bike.

> "*I would like to have more physical exercise, because that's better for me. That would for me be a reason not to use an e-bike, that would definitely be a point of concern*" (Interviewee 2)

Interviewees were unanimously positive about their cycling experience, and all mentioned the fun of commuting by e-bike and everyday cycling.

> "*I enjoyed the sunrise, the dew in the fields, the birds, the train passing by. And I thought, well, I'll be later than you, but at least I'm exercising!" Then, arriving at the university: "the janitor would look at me and say: 'you biked, didn't you? I can see that, your eyes are vivid, you have a blush on you'. So yeah, I would be happier upon arrival*" (Interviewee 8)

> "*It was definitely fun. I especially enjoyed the headwind. I would arrive at the university, not tired at all, but you're cycling, you get the fresh air*" (Interviewee 6)

iv. E-bike image

In the survey, participants tended to disagree with the statement that e-bikes are mostly interesting for older adults. In the interviews, the social stigma of assisted cycling being something for older adults was mentioned and did play a role for five of the eight interviewees. However, all of them stressed that it was not something that mattered to them personally, but might be a barrier to e-bike use for others. Some mentioned that e-bikes are not well-known. Pilots might help improve this image, as to the interviewees, their image of the e-bike image had changed through participation.

> "*When I told people I had an e-bike, a lot of them said, 'isn't that something for older people?' I said, try it! And they all liked it. So I really think that the image is bad... it's being related to older people, and no one knows how much fun it really is*" (Interviewee 6)

> "*Organizing pilots like these, I think that that would help. Looking at myself, I've really had a great experience (..) and people who like it share their experiences with people around them*" (Interviewee 1)

Most interviewees adjusted their initial view of the e-bike and three of them admitted that it was more of a positive experience than they thought beforehand. Four interviewees also stressed that they had gained insight in how they could benefit from e-bike use. A majority of the interviewees said they would recommend it to others, although not for use by older adults:

> "*Of course, it's practical; they would have to put in less physical exercise. But the chance of falling is much bigger. And if they fall, they are more easily injured*" (Interviewee 5)

v. Purchasing an e-bike

Despite their enthusiasm about using an e-bike, six out of eight interviewees stated that they do not need an e-bike at this point in their lives as they were getting around easily and cheaply with their current modes of transport. In line with the findings of the survey, they indicated that the availability of free public transport and low cost regular cycling made that the advantages of the e-bike were not considered worth the investment.

549 "*You know, students in Groningen consider 800 or 1000 euro's a lot of money for just*
550 *a bike. For the price of an e-bike, I could easily buy seven or eight other, normal*
551 *bikes"* (interviewee 4)
552
553 Only one survey respondent expressed the desire to buy an e-bike as alternative to current bus
554 commutes. For interviewee 8, an older student who commuted by car and had the longest
555 commute of all interviewees, participation in the pilot did lead to a re-valuation of her
556 commuting habits and a higher probability of purchasing one in the near future.
557
558 *"In one, or four years (..) For me, the reason to participate was to see whether the e-*
559 *bike can replace my car trips. And that's exactly what happened. So for me personally,*
560 *the pilot was of great value. But that doesn't mean that the next step is to immediately*
561 *buy one. It needs some time"* (interviewee 8)
562
563 Interviewee eight, who had the second-longest commute of all interviewees and travelled by
564 train, had recently bought a new, regular bike. She indicated that she would have taken an e-
565 bike into consideration, had the pilot been held before that purchase:
566
567 *"I had bought a new bike just before* [the pilot], *so that was unfortunate. Otherwise, I*
568 *would have thought about it"* (interviewee 1)
569
570 Thus, the willingness to buy an e-bike, or willingness to consider doing so, seems slightly
571 higher among respondents that currently commute by motorized transportation, and in the
572 case of the interviewees, live outside of the city and commute longer-distances on a day-to-
573 day basis. For those living in the city and doing short commutes by bus and bike, the e-bike
574 was not considered worth the investment. However, alternatively, interviewees mentioned to
575 be open to e-bike leasing. To the one interviewee commuting by car, a maximum monthly fee
576 of 50€ would be a maximum. Other interviewees indicated price ranges between 10 and 30€ a
577 month. Finally, despite the relatively low willingness to buy, all mentioned that the pilot led
578 them to be more open to buying and using e-bikes at later life stages, as an alternative mode to
579 bus, train and car use.
580
581
582

583 ## 4. Discussion

584 This study explored the benefits and limitations of e-bike use for university students. We
585 linked with an e-bike pilot at the University of Groningen to gain insight in travel choices and
586 individual experiences of students using the e-bike. Results indicate considerable potential for
587 student e-bike use. Students valued e-bike speed, ease of use, the enjoyable experience and
588 independency from public transport schedules. They stressed the importance of cyclists' own
589 responsibility in dealing with safety issues and saw little use in increased regulation. Barriers
590 to e-bike use after the pilot proved to be the high costs, and competition with low-cost regular
591 bikes and free public transportation. Despite the barriers related to the high price, our findings
592 support that there is a potential for e-bike use among a student population, and that gaining
593 experience with an e-bike through participation in a pilot may increase likelihood of e-bike
594 use in later life, and increase the acceptance of e-bikes as a suitable mode for everyday use.

595 Earlier studies have stressed the importance of a high speed and ease of use in e-bike
596 use (Popovich et al. 2014; Johnson & Rose 2015; Dill & Rose 2012). Students appreciated
597 these factors as well. They mentioned the enjoyment of speed, reduced effort, and mitigation
598 of wind influence to be central to their travels during the pilot. Also, it enabled them to reach
599 more destinations in shorter amounts of time. This is in line with other findings that stressed
600 the benefits of improved mobility and accessibility compared to bus use (Cherry et al. 2016).
601 Ease of use was also found to be an asset, confirming that effortless usage of an e-bike favors
602 a positive opinion, which can in turn leads to higher use (Wolf & Seebauer 2014).
603 Disadvantages were also mentioned, such as the preparations prior to the commute and the
604 need for secure parking. Popovich et al (2014) found e-bike users to be worried more about
605 the risk of theft. To students however, this was not seen as an important impediment, which
606 may be related to the fact that they did not personally own the bike.

607 Previous research suggests that users of conventional e-bikes are at higher risk of
608 injury than regular cyclists (Fishman & Cherry 2015). The present study showed that students
609 mostly attribute potential safety hazards to other e-bike users rather than to themselves. While
610 they expressed being aware of the risks, they stressed how own responsibility and adaptive
611 cycling mitigates that risk. We found little support for increased policy regulations.

612 Finally the goal of the e-bike pilot was to initiate a modal shift towards e-bike use. The
613 present study showed that students were very keen on using the bike while it was available to
614 them without any costs, and that having an e-bike led not only to decreased use of regular
615 bikes, but also to a decrease in bus rides, as aimed for by the initiators of the pilot. However
616 the willingness to buy was very low. Earlier studies mentioned purchase price of e-bikes as a

617 main barrier to e-biking (Jones et al. 2016). Students' relatively lower purchasing power and
618 availability of low-cost alternatives like regular cycling and public transportation are a main
619 barrier to student e-bike use. Interestingly, the social stigma of e-biking as a form of cheating
620 (Jones et al. 2016) was not a barrier to e-bike use by students. Some of them mentioned being
621 aware of the stigma of e-bikes being 'something for older people', but this did not hinder
622 them in using one themselves. This might in part result from what Peine et al (2016) have
623 termed the 'rejuvenation of e-bikes': newer e-bike designs being tailored to different, younger
624 adopter categories, thereby breaking with existing stereotypes.

625 A main strength of the present study is that it evaluated e-bike use in a population that
626 has thus far received little research attention, and to whom communication of sustainable
627 practices holds high potential in shaping (future) sustainable travel behavior. However, the
628 study is not without limitations. First, we took no objective measurement of changes in travel
629 behavior, so there is a risk of self-report bias. Another important limitation is that the
630 researchers were not involved in the survey design. The survey had shortcomings with respect
631 to collection of participant characteristics (age, home location, trip purposes), and definition
632 of terms such as safety and sustainability, which might have been interpreted differently.
633 However, the data were informative and were complemented with carefully formulated
634 interview questions. Finally, the sample was small, non-representative and self-selected.
635 Therefore, the findings might not be generalizable to other populations. However, students
636 were offered the opportunity to try an e-bike for free, and some interviewees stated to not
637 exactly know what an e-bike was prior to the pilot or what pilot participation entailed. Thus,
638 self-selection may not have been very strong because students might have participated
639 regardless of their view on e-bikes.

640 Future research may further explore e-bike use and its potential for use in early
641 adulthood using objective registrations of travel behavior, for example by means of GPS
642 tracking. By combining such studies with representative surveys among larger samples, more
643 insight could be gained into the factors that enable a modal, sustainable shift from
644 conventional motorized transport to e-bike use. Issues of self-selection may be addressed by
645 conducting experimental studies, in which participants are randomly assigned by the
646 researchers to conditions of using an e-bike or control conditions.

647 A main practical impediment to e-bike use among students was found to be its high
648 purchase price and the competition with cheap regular bikes and public transportation. Future
649 studies may further examine this relationship and the possibilities of providing students with
650 more appealing options such as e-bike financing, leasing or renting.

In general the results of the present study support the idea that e-bike use can be effective in replacing excessive use of free public transportation by students. These insights may be used in future efforts directed at realizing a modal shift in student travel behavior. The positive attitudes of students towards e-bike use indicate increased acceptance of e-bikes as an everyday mode of transport and suggest likelihood of use in later life. Finally, our findings provide support for the method of e-bike pilot testing in attracting new user groups.

5. Conclusion

Persistent high levels of conventional motorized transportation around the world continue to underscore the importance of adopting more sustainable transport alternatives such as the e-bike. Our findings show that students highly valued e-bike use, although the high costs of e-bikes cannot compete with low-cost regular bikes and free public transport. Yet, the present study suggests that giving young adults the opportunity to try an e-bike may increase their acceptance of e-bikes for everyday use in the present and in their future lives.

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